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Chemometric analysis as a tool for confirmation of join meteorites fall- case study

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Introduction:

Ten specimens of ordinary chondrites from two different campaigns were investigated. An analysis was carried out using a unique gamma spectrometry system to obtain the optimal measurement conditions for the quantitative identification of the radioactive isotopes. Short-lived radionuclide concentrations can be considered, as a specific fingerprint of the chondrite terrestrial age, to confirm whether meteorites originate from a single fall.

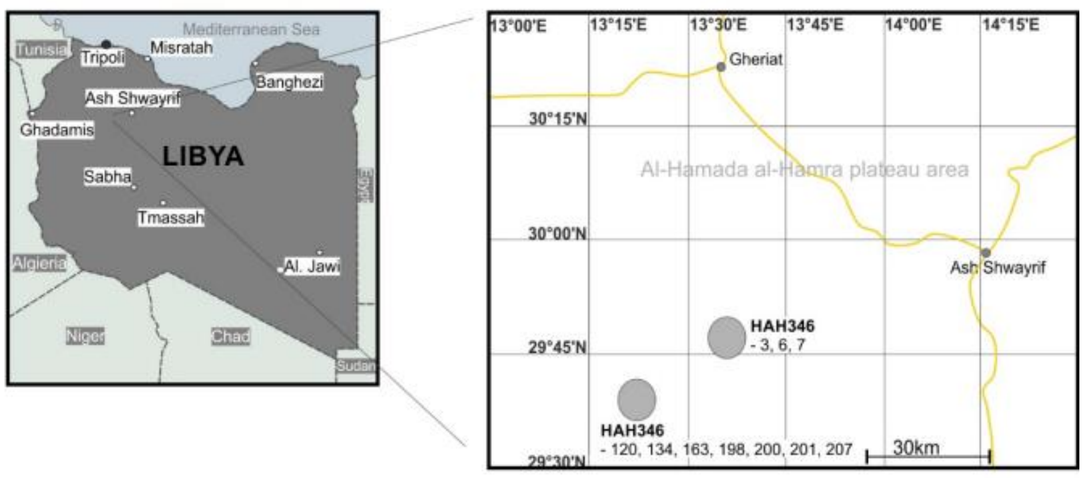

Figure 1. Map of the HaH 346 items found.

Materials and methods:

The unique, low-background spectrometric system (Figure 3) used in this study provided the opportunity to work in three independent modes—coincidence, anticoincidence, and singles. Conducting measurements in various modes led to optimal measurement conditions for the quantitative and qualitative identification of radioactive isotopes, mostly anticoincidence. Detection efficiency calibration is used for quantitative analysis of the chondrites. In practice, the gamma spectrometry system allows for the quality and quantity analysis of the spectrums. Routinely, the background has been subtracted from the raw spectra. Each measurement for an individual sample was carried out over at least four days, over 320,000 s to a maximum of 800,000 s; thus, the uncertainty of the measurement did not exceed 5% for ^{40}K, 10% for ^{22}Na, ^{26}Al, and ^{54}Mn

Due to the various geometries of the samples, the detection efficiency of the specimens was established on the basis of LabSOCS (Laboratory Sourceless Calibration Software) (CANBERRA Industries, Inc., Meriden, CT, USA). This method allowed the detection efficiency values (Figure 4) to be corrected based on the different chemical composition of the analyzed materials [33–35]. The chemical compositions of the meteorites were analyzed using the X-ray fluorescence XRF technique.

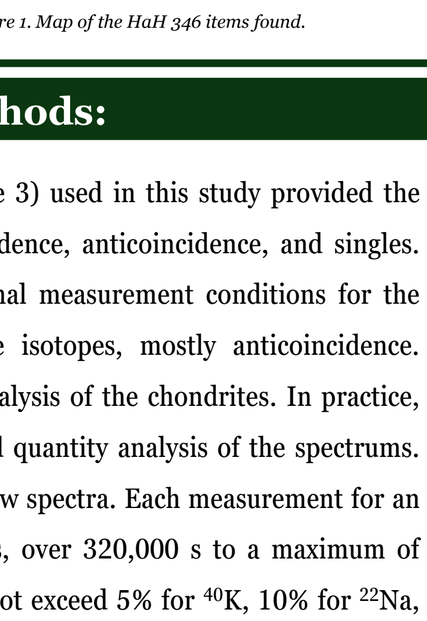

Figure 2. Unique gamma spectrometry system with an active anticoincidence shield.

Results:

Chondrite radiometric studies enabled a detailed analysis of the activities of radioactive isotopes—the short-lived ^{22}Na, ^{54}Mn, ^{60}Co, and long-lived ^{26}Al, ^{40}K. The HaH 346 group of chondrites was classified in February 2021. The data sets have been analyzed based on multivariate chemometric techniques, including K-means, PCA, and clustering analysis, to derive essential information and confirm similarities or significant differences between the studied specimens. In this study, low-background gamma spectrometry was used to confirm the identity of a set of ordinary chondrites found in 2018 and 2019, by different expeditions, in a part of the Al-Hamada al-Hamra desert, in the region of Al-Dzabal al-Gharbi, in Libya.

Figure 3. Photo of two HaH 346 specimens from two different expeditions (a) Close to Ashuwairif town (HaH 346-201), (b) Close to Gheriat town (HaH 346-3).

K-means method is a useful technique for elucidating subtle but pertinent information that is present in analytical results and groups similar data points together. The final clustering scores of the set data were derived from the first PC (PC-1, 61.40%) and the second PC (PC-2, 19.52%) and are illustrated

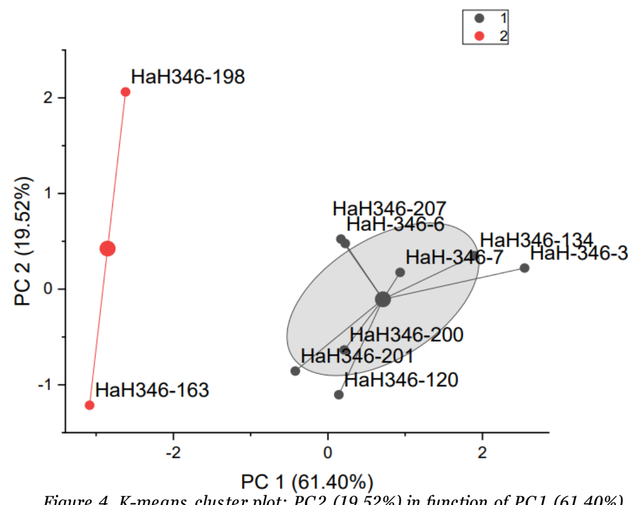

Figure 4. K-means cluster plot: PC2 (19.52%) in function of PC1 (61.40%)

The Euclidean distance method of the clustering analysis confirmed the grouping of the samples into two different clusters.

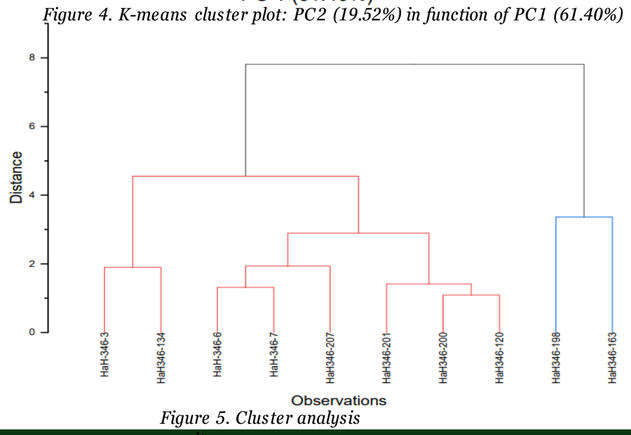

Figure 5. Cluster analysis results.

Conclusions:

Short-lived radionuclides are sensitive tools to estimate the terrestrial age of chondrites, even if the fall took place in a relatively short time interval. ^{54}Mn is the most representative for a comparison of specimens originating from different falls. Radioactivity levels of ^{54}Mn in HaH 346-163 and HaH 346-198, is on average, twice lower than in the case of other specimens and are equal to 13.3 and 22.5 Bq/kg, while the average value for other specimens is equal to 35.9 ± 7.2 Bq/kg.

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References:

Długosz-Lisiecka, M., Jakubowski, T., Krystek, M.; ElMallul, A., Radioactive Isotopes as a Tool for Pairing Identification of the HAH 346—Hammadah al Hamra 346—Ordinary Chondrites from Two Separate Find Areas, (2022) Minerals, 12 (12) DOI: 10.3390/min12121553.

Alexeev, V.A.; Laubenstein, M.; Povinec, P.P.; Ustinova, G.K. Variations of cosmogenic radionuclide production rates along the meteorite orbits. Adv. Space Res. 2015, 56, 766–771.

Povinec, P.P.; Sýkora, I.; Macke, R.J.; Tóth, J.; Kornoš, L.; Porub˘can, V. Radionuclides in Chassigny and Nakhla meteorites of Mars origin: Implications for their pre-atmospheric sizes and cosmic-ray exposure ages. Planet. Space Sci. 2020, 186, 104914.